COMPUTER-BASED SKILL QUALIFICATION TESTING: DEVELOPMENT AND VALIDATION

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An alternative to present SQTs for tactical data systems is the concept of a computer-based embedded SQT administered on the operational system or simulator to accomplish standardized, objective, hands-on skill qualification assessment. This paper describes a computer-based SQT Hands-On Component developed for TACFIRE Artillery Control Console Operators, MOS 13C, using the PLANIT courseware authoring language. The SQT complies with TRADOC policy and procedures for SQT development and validation (TRADOC Reg 351-2, Pam 351-2). An expert tryout for content validity and a representative-soldier tryout for feasibility of administration were conducted. A method for diagnosing and correcting logic errors in the courseware (vs. operators' errors) was applied. Benefits of computer-based SQT testing include: maximum fidelity attained by utilizing the operational system; control, monitoring, and scoring performed by the tactical system computer; centralized or field unit testing capability; immediate, detailed performance feedback provided; test results compatible in format with TRADOC guidelines.

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1.0 INTRODUCTION

1.1 Statement of the Problem

The Skill Qualification Test (SQT) is a primary means the Army uses to assess soldiers' proficiency in performing critical tasks of their military occupational specialties (MOSs). It contains performance-oriented and criterion-referenced tests on critical tasks selected from the soldier's manual for a duty position. Test results feedback is provided to soldiers, supervisors, training managers, and training/test developers. The SQT usually contains a written Skill Component (SC), a Hands-On Component (HOC), and a Job Site Component (JSC).

Although the SQT program was designed to maximize hands-on performance testing, problems of standardization, inter-rater scoring reliability, extensive time and resource requirements, training of test administrators, and overall administrative feasibility have attenuated its success. Much skill qualification testing has become primarily written in nature, via the SC or a written Alternate HOC. The written tests allow for standardized administration and scoring, but often have low fidelity to actual job performance requirements. The intended objective of performance-based, criterion-referenced SQT testing could be more effectively realized by a) increased fidelity of the SQT (that is, more similarity) to job requirements and task performance; b) reduced reliance on written components; c) reduced time between test administration and test results; and d) increased feasibility of unit level SQT administration.

1.2 Concept of Computer-Based Embedded Testing

The increasingly extensive use of the computer in military systems offers an opportunity to alleviate present shortcomings common to conventional SQTs for tactical data and weapons systems. The concept is computer-based embedded SQT testing in which the computer of a tactical weapons system monitors, controls, and scores a test on actual job tasks administered on that system itself (or a simulator). This paper describes the development and validation of a computer-based SQT Hands-On Component (HOC) for the TACFIRE Artillery Control Console Operator (ACCO), MOS 13C.[2]

[1]The views expressed in this paper are those of the authors and do not necessarily imply endorsement of the Department of the Army or the Army Research Institute.

[2]Work described in this paper was performed by Honeywell Inc. for the U.S. Army Research Institute for the Behavioral and Social Sciences, contract no. MDA903-79-C-0386.

The SQT HOC is comprised of courseware written in a computer-assisted instruction system and authoring language called PLANIT. It is administered in an embedded mode on the TACFIRE tactical system either in the school or field setting. The SQT complies with TRADOC policy and procedures for SQT development and validation (TRADOC Reg 351-2, Pam 351-2) and offers many advantages over conventional HOC testing for the MOS 13C duty position.

1.3 Background

1.3.1 TACFIRE System. The TACFIRE system selected as the testbed for applying the embedded SQT concept is a computerized TACtical FIRE direction system designed to coordinate the command, control, and communications functions within and among all levels of the field artillery system from corps to forward observers. TACFIRE may be conceptualized as an interrelated set of subscribers, each of whom has access to a common data base and a powerful set of applications software. The artillery control console (ACC) shown in Figure 1 is the principal man-machine interface in the TACFIRE system.

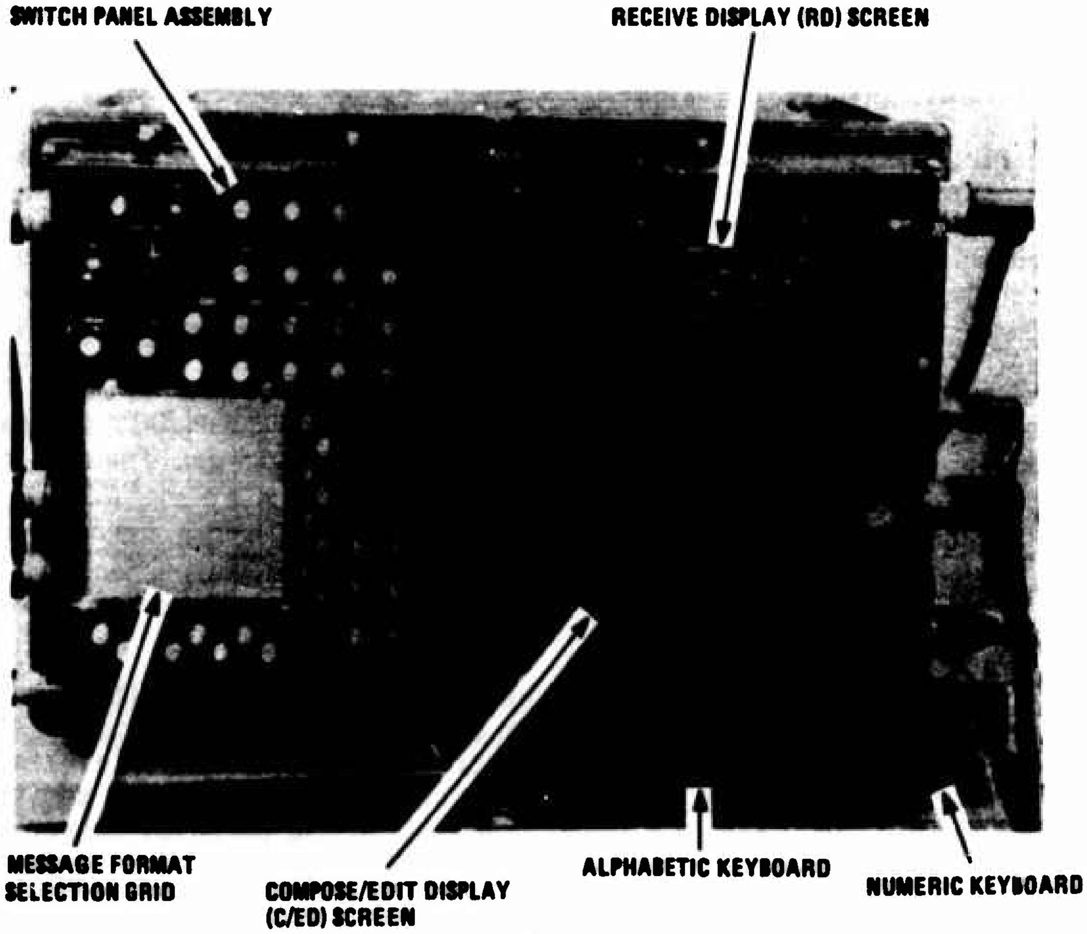

Figure 1. TACFIRE Artillery Control Console

The ACCO is a grade E6 or E7 noncommissioned officer responsible for maintaining and updating the TACFIRE data base. His functions include: entering data required for artillery target intelligence, fire planning, tactical and technical fire control, and commander's criteria; controlling communications among the network of TACFIRE

subscribers; and initiating , processing, and/or terminating artillery fire missions. Task activities for which the ACCO has responsibility include:

- o Receiving and interpreting information. The ACCO receives information from the subscriber network on the receive display (RD) screen. This information is encoded in TACFIRE specific formats, and requires that the ACCO be skilled in interpreting the information and acting quickly.
- o Composing and sending messages. The ACCO enters data into the system via special message formats on the compose/edit display (C/ED) screen, then makes proper switch-actions to initiate processing of the data and transmission to designated on-line subscribers.

1.3.2 PLANIT System. The embedded SQT for the TACFIRE system was written in Programming LANguage for Interactive Teaching (PLANIT), a powerful computer-assisted instruction system and courseware authoring language useful for preparing and administering training and evaluation scenarios via computer terminal. Courseware is constructed either interactively or off-line, and the author may execute and/or edit a lesson at any time. PLANIT automatically maintains an audit trail of each student's progress through a course, thus relieving the instructor or scorer of tedious record-keeping responsibilities.

The PLANIT operating system is made machine transportable and has been installed on computer systems supporting FORTRAN, PASCAL, and TACPOL (language used for TACFIRE). For the TACFIRE AN/GYK-12 application, enhancements to the operating system software were implemented to extend PLANIT's capabilities to a specific hardware system. PLANIT's enhanced language for TACFIRE permits the lesson author courseware control of switch indicator lights, and interprets the operation of ACC function keys. Outputs may be directed to either of two screens, to the electronic line printer (ELP), or to the switch panel assembly (SPA). Inputs are processed from the C/ED screen, the alphanumeric keyboard, or the SPA. Under control of PLANIT's enhanced language for TACFIRE, the TACFIRE ACC can operate exactly as it would under control of the operational system software in tactical mode.

2.0 DEVELOPMENT OF COMPUTER-BASED SQT

2.1 Requirements

The development of the HOC offered a unique challenge for complying with regulations that do not explicitly address issues for computer-based SQT testing. Although some steps identified in TRADOC Pam 351-2 were not relevant (for example, training hands-on test scorers and assessing inter-rater reliability), and other additional developmental steps were included, the TRADOC regulation and pamphlet served as adequate guidance for the development process.

2.2 Development Process

The major activities conducted during development of the SQT were:

1. Select tasks for testing.
2. Assign tasks to SQT components.
3. Develop SQT plan.

4. Develop test materials.
   a. Collect task performance data.
   b. Organize hands-on tests.
   c. Program courseware for hands-on tests on commercial computer.
   d. Try out courseware materials on TACFIRE computer.
   e. Revise hands-on tests.

5. Develop support documentation--"Manual for the Administration of the Hands-On Component" (MAHOC), SQT Notice hands-on test worksheets, "Data Supplement," and "Operator's Guide for Preparing SQT Materials."

6. Conduct expert tryout.

7. Submit initial draft.

8. Conduct soldier tryout.

Pertinent characteristics of the finalized TACFIRE embedded SQT HOC are summarized in Table 1. Koch, Pine, and Steinheiser (1980) and Koch, Englert, and Vestewig (1981) provide details of the development process for the SQT.

TABLE 1. CHARACTERISTICS AND CAPABILIITES OF THE TACFIRE EMBEDDED SQT HANDS-ON COMPONENT

<u>Objective</u>
- Assess qualification of artillery control console operator (ACCO), MOS 13C, skill levels 3 and 4.

<u>Conditions of Testing</u>
- Delivered on operational tactical TACFIRE equipment using TACFIRE AN/GYK-12 computer or on TACFIRE Training System (TTS).
- Capability of simultaneous testing of soldiers.
- High fidelity to soldier's manual (FM 6-13C3, FM 6-13C4) tasks.
- Standardized administration at either centralized (Field Artillery School) or field unit installations.

<u>Test Organization</u>
- HOC composed of hands-on tests.
- Automatic presentation of all necessary test instructions and hands-on test conditions, standards, and performance measures.

<u>Test Scoring</u>
- Scoring performed automatically by TACFIRE computer.
- Each hands-on test scored "GO" or "NO-GO" based on number of performance measures passed and satisfaction of time limit standard.
- Qualification on SQT based on criterion percentage of hands-on tests scored "GO."

<u>Test Results Feedback</u>
- Immediate test results and performance feedback.
- Performance feedback specific to items at the performance measure level.
- Individual Soldier's HOC Report providing tabulation of results.
- HOC Record Sheet providing official record of test results.

3.0 VALIDATION OF SQT HANDS-ON COMPONENT

3.1 <u>Validation Plan</u>

The validation phase of the SQT development involved the production of a validation plan and two formal tryouts of the HOC in accordance with the TRADOC guidelines

(TRADOC Pam 351-2). The objective of the validation was to examine the HOC for content validity, accuracy, perceived fairness, and administration feasibility. The strategy for validation of the HOC is reflected in the flow-chart in Figure 2.

Two unique issues were important in assuring an acceptable validation of the computer-based, embedded SQT. The first concerned a necessary distinction between logic errors in the hands-on test courseware and unfair or inaccurate test content per se. Thus, two types of validation were required--one for courseware materials and one for hands-on test technical content. The second issue concerned the requirements for administration (using the resources of a typical unit) and maintainability associated with a computer-based SQT.

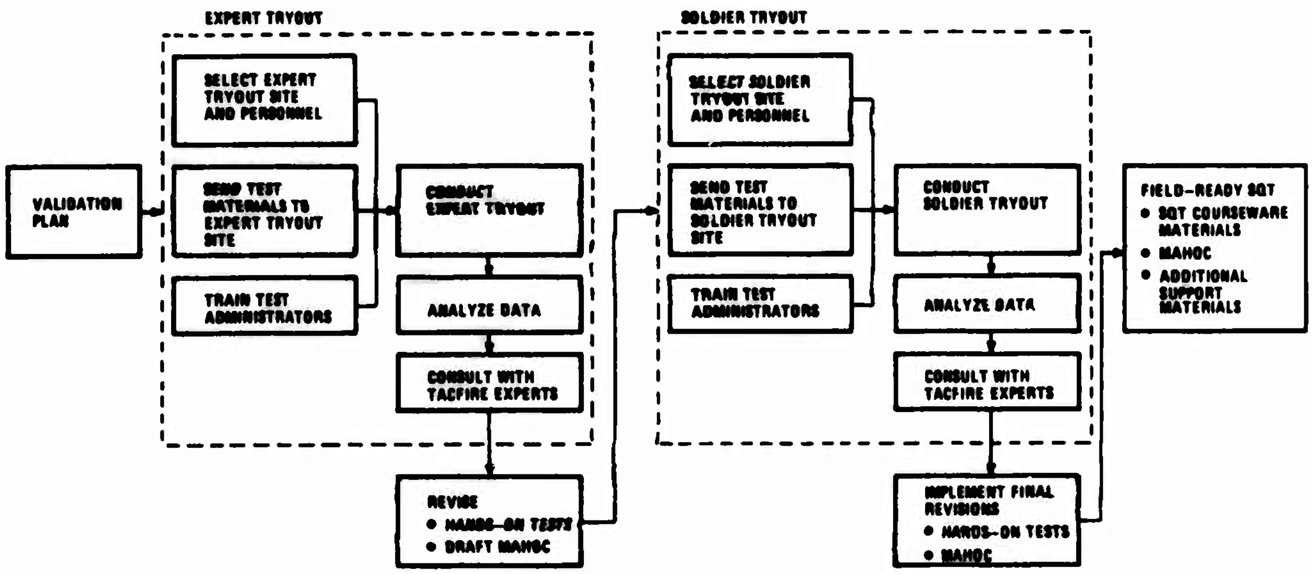

Figure 2. Flow Diagram of SQT HOC Validation Process

3.2 Expert Tryout

3.2.1 Objectives. The objectives of expert tryout of the TACFIRE SQT HOC were to:

- Provide TACFIRE subject matter experts an opportunity to systematically review each hands-on test for accuracy of the task procedures as defined by the soldier's manual.
- Examine the draft MAHOC for content, readability, and clarity.
- Identify and implement any necessary revisions to the hands-on tests, instructions, and draft MAHOC.
- Determine test administration requirements, including time to set up and administer the hands-on tests.

3.2.2 Procedure. The participants in expert tryout were 14 instructors in the TACFIRE Advanced Training Program at the U.S. Army Field Artillery School, Fort Sill, Oklahoma. Both noncommissioned and commissioned officers were included in the sample. Five experts completed the SQT3 HOC (the HOC for skill level 3), and six experts completed the SQT4 HOC (the HOC for skill level 4). Each of the experts served both as test administrator and examinee. A two-hour workshop was conducted to familiarize the participants with procedures for preparing the computer-based HOC to be administered.

During expert tryout, the participants executed the support procedures routine to prepare the HOC to be administered and then performed each of the hands-on tests in the same manner as an examinee would. Data of various types were collected to meet the stated objectives. Table 2 summarizes the type, purpose, and collection time of these data.

TABLE 2. EXPERT TRYOUT DATA COLLECTION

Type	Purpose	When Collected
Expert Review Form	Examine task domain sampling, hands-on test accuracy, test instructions, and test fairness	End of each hands-on test
Draft MAHOC Review Form	Examine Draft MAHOC	End of workshop to train test administrators
Support Procedures Review Form	Examine test administrator's support procedures	End of test session
General Computer Instructions Review Form	Examine general HOC instructions to the examinee	End of test session
Error Data	Examine hands-on tests	Recorded automatically by computer during test session

3.2.3 Results. Responses to review forms on the draft MAHOC, support procedures, and general instructions identified areas for revision. The section in the MAHOC dealing with computer malfunction recovery was considered inadequate, and certain portions of the general instructions were rated as unclear. Prerequisite data provided on the ELP for some hands-on tests were difficult to read due to poor printer type element quality and caused some undeserved errors. Responses on the expert review forms dealing with technical content of each hands-on test identified problems in these areas: task requirements unclear; only one try allowed for selecting message format switches; optional data entries/blanks not allowed; alternate legal forms of data entry not allowed; answer match lines containing typographical errors.

Analysis of experts' errors on the hands-on tests yielded three identifiable causes of performance measure failures:

- o Operator error--incorrect switch-action or failure to complete hands-on test within appropriate time limit.
- o Courseware logic error--mistakes in the PLANIT courseware that may cause unwarranted performance measure failures.
- o Inappropriate time standard--insufficient time allowed for completing hands-on tests.

Distinguishing operator errors from logic errors required an examination of the printer output for inconsistencies between the expert's response and his detailed test performance feedback.

The remainder of the error analysis focused on the operator errors. Four classifications of operator errors and the average frequency with which they were committed are: a) incorrect data entry--52%; b) incorrect message format selection--23%; c) incorrect switch action--13%; d) excessive time to complete the task--12%.

3.2.4 Revisions. Revisions to the hands-on test materials based on expert tryout data included: expanding the computer malfunction recovery section of the MAHOC; developing a "Data Supplement" containing hardcopy of prerequisite data for all hands-on tests; rewriting portions of general instructions in simpler language; clarifying task requirements; implementing two tries to select correct message format switches; allowing optional data entries/blanks; allowing alternate legal forms of data entries; correcting typographical errors in answer match lines; correcting courseware logic errors; revising inappropriate time limit standards. After modifications to the SQT HOC had been implemented, the hands-on tests were again administered to a subset of the expert tryout participants to verify accuracy of the revisions.

3.3 Soldier Tryout

3.3.1 Objectives. The objectives of soldier tryout of the TACFIRE SQT HOC were to:

- Determine the HOC's administrative feasibility in a realistic test setting with representative soldiers in the MOS.
- Continue to examine the hands-on tests for accuracy, appropriateness, and fairness.
- Perform statistical analyses of hands-on test performance data.
- Continue to examine the draft MAHOC for clarity and completeness.
- Implement revisions to the hands-on tests, instructions, and draft MAHOC where necessary.

3.3.2 Procedure. The soldier tryout participants were 22 soldiers in MOS 13C stationed at Fort Sill, Oklahoma. Ten staff sergeants completed SQT3 HOC and ten sergeants first class completed SQT4 HOC. Personnel from the Directorate of Training Development, U.S. Army Field Artillery School served as test administrators.

The type, purpose, and collection time of soldier tryout data are shown in Table 3. The data derived from these sources were analyzed according to the process depicted in Figure 3.

TABLE 3. SOLDIER TRYOUT DATA COLLECTION

Type	Purpose	When Collected
Soldier Review Form	Examine hands-on tests for fairness, accuracy, and clarity of instructions	End of test session
General Computer Instructions Review Form	Examine general HOC instructions to the examinee	End of test session
Error Data	Examine hands-on tests; perform statistical evaluation of HOC	Recorded automatically by computer during test session
Timing Data	Determine test administration requirements; examine performance standards for task completion time	Recorded automatically by computer during test session

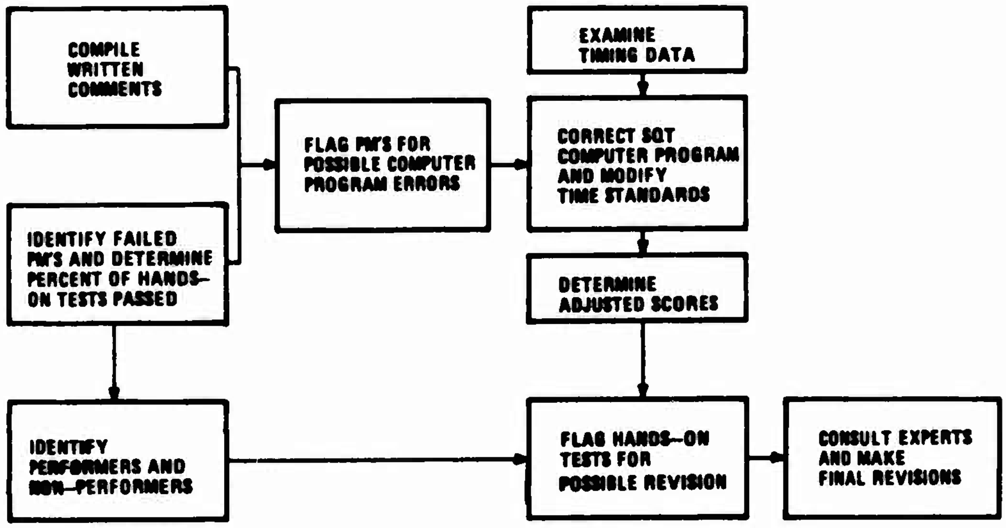

Figure 3. Flow Diagram of Error Analysis and Test Revision Process Following Soldier Tryout

3.3.3 Results. Responses on the general instructions review forms identified two portions of the instructions that some soldiers found unclear--action to take after a discovered error, and amount of help expected from the test site manager. Responses on the soldier review forms evidenced that a large percentage of the soldiers viewed the SQT HOC as a fair and acceptable measure of their ability to perform job duties.

Errors committed on the hands-on tests were again categorized by source--operator error, courseware logic error, and inappropriate time standard. The type and average frequency of errors attributable to the operator are: a) incorrect data entry--51%; b) incorrect message format selection--18%; c) incorrect switch action--21%; d) excessive time to complete the task--10%.

Analysis of the timing data for the representative soldiers provided an empirical basis for examining the adequacy of the hands-on test time limit standards. An average of 83% of soldiers taking SQT3 HOC finished the hands-on tests within given time limit standards; 92% of those taking SQT4 HOC finished within the standards. Three specific criteria were used to judge the adequacy of each hands-on test time standard: a) equals approximately double the average time required by representative soldiers; b) exceeds the upper limit of the range of task completion times; c) equals a value defined by training developers to be mission-related.

3.3.4 Revisions. Revisions to the hands-on test materials based on soldier tryout data included: rewriting portions of general instructions; including SQT HOC administration time guidelines based on soldier tryout in the MAHOC; correcting courseware logic errors; adjusting hands-on test time standards.

4.0 ADMINISTRATION AND MAINTENANCE ISSUES

4.1 Issues in Administering the SQT HOC

TRADOC regulations for SQT development stress the importance of one feature that should characterize an SQT--relative ease of administration (TRADOC Reg 351-2). To meet this criterion, the SQT should be easy to administer by NCOs at the E6

level or higher, be accompanied by comprehensive and simple guidelines for test administrators, and require only the personnel and equipment resources available at a typical unit. These became the objectives for administering the TACFIRE embedded SQT. Issues important for SQT administrative feasibility include qualifications of test administrators, system configuration and status, test security, and disposition of test results.

With the MAHOC as a reference, administering the computer-based SQT is designed to be a turn-key operation for the test administrator. He will be able to perform test set-up procedures explained in the MAHOC, administer the SQT to soldiers, and collect the examinee test results with no prerequisite computer programming experience or outside assistance.

The SQT HOC at either skill level 3 or 4 can be administered on any existing TACFIRE system configuration, that is, battalion or division artillery, at centralized locations or field unit locations. The SQT materials written in PLANIT courseware are transportable via standard TACFIRE input-output medium--magnetic tape cartridge. The load procedures are comparable to those performed by an ACCO for TACFIRE tactical system software. In the event of external threat or other emergency, the TACFIRE system can be restored to operational status immediately by loading tactical system software.

Test security for the computer-based SQT depends on safeguards against compromise by those who are not authorized to administer the SQT and safeguards against unauthorized modifications to the courseware. The PLANIT software provides for both safeguards since log-in identifications used by operators and examinees restrict their access to only those functions in the courseware intended for their use.

For the computer-based SQT, the scoring procedure will differ from the conventional approach. The TACFIRE computer will perform the scoring for each examinee, tabulate test results, and print a complete HOC Record Sheet. This record sheet can be transcribed directly to the SQT marksense form used by the training standards officer to compile test results.

4.2 Maintainability Issues and Procedures

There are four general levels of maintenance for the computer-based, embedded SQT considered important for an overall goal of ease of maintenance. The levels of maintenance are listed in Table 4 ordered from specific to general, together with the primary objective associated with each.

The aspects of TACFIRE equipment maintenance relevant to actual system operation also affect SQT operation. In the event of equipment malfunctions, the testing is halted but no performance data are lost from core memory. When the system is restored, PLANIT automatically resumes HOC testing at the point where each examinee was stopped.

Annual revisions to an SQT mandated by TRADOC are accommodated by a large base of validated hands-on tests. The SQT developers need only select a different subset of hands-on tests each year to optimally represent extant job duties. This selection requires no modifications to the courseware.

TABLE 4. MAINTENANCE OBJECTIVES

Level of Maintenance	Primary Objective
1. Maintenance for TACFIRE equipment on which the SQT HOC is administered.	Ensure test reliability by minimizing equipment failure and down time.
2. Annual revisions to SQT contents in accordance with TRADOC regulations.	Provide flexibility to use developed and validated hands-on tests for more than one test period.
3. Modifications and additions to the courseware comprising hands-on tests.	Provide capability to implement modifications and additions to the courseware interactively, easily, and rapidly.
4. Enhancements and troubleshooting support for the software system.	Provide quality assurance for system software.

New interface requirements and operating system software releases will drive the training and testing requirements for TACFIRE and any evolving, complex system. Supplementing the TACFIRE SQT with new or revised test materials is an important capability to accommodate extensions in the scope of the SQT. A technician with computer programming experience has the qualifications to edit existing courseware and develop new courseware for the TACFIRE embedded SQT. The more common types of courseware modifications that will be required are quite simple and can be accomplished interactively from the ACC terminal at any time.

At the most general level of maintenance for the computer-based SQT is support of any enhancements for the PLANIT operating system software. The evidence for maintainability and supportability of the PLANIT software is derived from many trouble-free installations of PLANIT nationwide, spanning a wide variety of applications.

5.0 CONCLUSIONS

Conclusions warranted by the results of the computer-based SQT development and validation may be relevant both as an overview of the present work and as research and development issues for other SQTs designed to be delivered on operational tactical data systems. First, the TACFIRE embedded SQT appears to be enthusiastically accepted by the user community. The extensive involvement of subject matter experts and TRADOC personnel during the development, validation, and review process, together with the developer's responsiveness to TRADOC regulations and user input, are thought to be important contributors to this acceptance.

The TACFIRE application of computer-based, embedded HOC testing is feasible and effective in fulfilling the intent of the Army SQT program. Performance of hands-on tests on the TACFIRE equipment closely resembles the performance of actual job duties. The TACFIRE computer accomplishes objective and accurate scoring of hands-on tests. The SQT is also feasible from the standpoint of administration and maintenance, requiring no programming experience to administer and no other resources or equipment than those available at the typical field unit. The PLANIT courseware materials are structured in a modular format and are easy to modify and supplement.

Compliance with TRADOC regulations for SQT policy and procedures by the computer-based SQT does not differ significantly from conventional SQTs. The validation plan, expert tryout, soldier tryout, data analysis, and test content revisions were conducted in accordance with regulations. The MAHOC closely follows the TRADOC recommended format. Test results are computer-generated in a form compatible with TRADOC SQT scoring procedures.

PLANIT has been a successful vehicle for development of the TACFIRE embedded SQT. PLANIT capabilities and advantages include: extensive record keeping of student performance; analysis of incorrect answers to provide detailed feedback; transportability of courseware; ease of courseware modification. The success of PLANIT in the implementation of the TACFIRE embedded SQT recommends it as a candidate for other developments on computer-based tactical data systems.

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